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RACIC report

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RACIC report

A FEASIBILITY STUDY OF A REMOTE AREA LAND TRANSPORTATION CONCEPT

Report No. RACIC-TR-59

March 16, 1967

prepared for

ADVANCED RESEARCH PROJECTS AGENCY
PROJECT AGILE

Contract No. F33657-67-C-0810
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by

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June 9, 1967

Advanced Research Projects Agency
Office of the Secretary of Defense
Washington, D. C. 20301

Attention Mr. A. N. Tedesco
Project AGILE

Dear Sir:

Enclosed are five copies of our report "A Feasibility Study of a Remote Area Land Transportation Concept", Report No. RACIC-TR-59, which was prepared in response to your request.

We will welcome any comments you may have in regard to this study.

Sincerely,

John W. Murdock

John W. Murdock
Project Director
RACIC

JWM:sel
Enc. (5)

cc: According to Distribution List

ACKNOWLEDGMENT

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PREFACE

This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by ARPA/AGILE under Contract No. F33657-67-C-0810.

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A FEASIBILITY STUDY OF A REMOTE AREA LAND TRANSPORTATION CONCEPT

by

M. M. DeLong and D. N. Goss

INTRODUCTION

The cost of constructing and maintaining a conventional all-weather feeder-road network in the remote areas of tropical and semitropical regions of developing countries is very high and often cannot be justified. However, some type of all-weather feeder-transportation capability is necessary to increase economic activity, enhance civic action programs, and maintain adequate security against insurgency.

A. N. Tedesco, Mobility Program Manager, Project AGILE, of the Advanced Research Projects Agency, suggested a land-transportation concept that may provide a solution to this problem and has requested the Remote Area Conflict Information Center at Battelle to outline this concept in some detail and obtain a preliminary assessment of its feasibility.

The concept consists of a vehicle-roadway combination. The vehicle is a commercially available item presently used as an off-road vehicle by several industrial concerns; its most distinguishing feature is the type of tire used. Relative to ordinary automotive tires, it has large ground-contact area and volume and a minimum number of fabric plys; it uses a very low inflation pressure. In some cases, the vehicle has an amphibious or fording capability. The vehicle is matched with a minimal roadway. This minimal roadway makes possible greater vehicle speed than can be achieved in off-road operation. However, maximum use is made of the vehicle's off-road ability to minimize the need for such high-cost, road-construction operations as roadbed and surface preparation and construction of drainage facilities and bridges.

The scope of this study covers only the description and a preliminary assessment of the concept's feasibility. No attempt was made to predict the overall demand for or benefit from this concept. It was assumed that the concept would be utilized in the example applications and that other critical problems, such as fuel and spare-parts distribution, management of the operations, training of personnel, etc., could be overcome.

The concept appears feasible in the context of the requirements considered in this study; that is, as a feeder-transportation concept, it could offer a significant advantage over existing fair-weather or all-weather alternatives. The next appropriate step in evaluating the concept would be to conduct a simulated or actual pilot test to obtain more definitive data on performance and costs.

SUMMARY

Low cost and adequate capacity were the two primary characteristics considered in evaluating the feeder-transportation concept. The problem in trying to obtain such characteristics arises from the extreme weather and topographical conditions which prevail in tropical areas.

Existing native trails now serving as feeder-transportation matrices are often impassable for conventional vehicles for one-fourth to one-third of the year because of the heavy annual monsoon rains. Even when the trails are passable, the surface is very rough and often very dusty, and this imposes severe operating conditions on conventional vehicles. Consequently, conventional vehicles have a relatively low utilization rate and short life (e.g., 50,000 miles/3 years). Conventional all-weather roads could alleviate many of these problems and, in fact, are often used as arterial transportation links. However, they are simply too expensive (e.g., \$25,000-\$50,000/mile) to be extended to cover the feeder-transportation situation.

ARPA/AGILE specified the type of vehicle for this concept. The three vehicles considered were the Rolligon Corporation's Marsh Skeeter (2000-lb payload), the Shell Development Company's Shell Crab (4000-lb payload), and Shell's modified Ford F-600 truck (6000-lb payload). A detailed description of the vehicles is presented in Appendix A. These vehicles use a unique type of tire (large volume, large contact area, flexible carcass, low inflation pressure (see Table 1, page 5, for additional details) and are especially suited for the situation under consideration.

The very nature of an off-road vehicle (relatively low payload-to-weight ratio and operational speeds compared with conventional highway vehicles) raised the question as to whether the ROTE*-vehicle/minimal-road combination could provide sufficient capacity.

Studies of transportation characteristics in remote areas indicate that a traffic volume of 50 vehicles/day or less (75 to 90 percent of these are trucks and buses) on feeder links is typical. The payload of these vehicles ranges from 4000 to 25,000 pounds, depending on the vehicle size and type and the road condition. Assuming this to be a reasonable estimate of the capacity required, the capacity of the ROTE-vehicle/minimal-road combination concept was established at a maximum of 40 tons/day passing any point. This would be equivalent to 15 to 25 ROTE vehicles/day passing a point.

Depending on terrain conditions, one of three different minimal-road construction techniques would be necessary:

Minimal Road Type	Construction Operation
I	Improvement of existing paths or trails
II	Establishment of roads through virgin areas by clearing surface vegetation and using the natural earth surface as the roadway
III	Establishment of roads through virgin areas by clearing surface vegetation and performing a minimum amount of cut-and-fill operations.

*ROTE vehicle: Rolligon bag or Terra-tire Equipped vehicle. This term is used throughout the report to indicate vehicles of this general type.

There is a wide variation in road and vehicle costs between different developing countries and cost figures averaged over more than one country lose much of their meaning. To avoid this problem for analyzing the feasibility of the concept, the area of Sakon Na Khon Province in northeast Thailand was selected. The selection was made after discussions with ARPA/AGILE and AID personnel. The need described was provision of transportation links from district administrative centers to the provincial capital (Sakon Na Khon) or to existing all-weather roads leading to the capital.

Three possible road segments, totaling 46.9 miles, were selected. Depending on the surface and topographical characteristics, the estimated minimal road construction costs (for a road with a 3-year life) ranged from $800 to $4000/mile. The average cost would be $1300/mile with an annual maintenance cost of $300/mile. Conventional all-weather roads in this area were estimated to cost a minimum of $30,000/mile.

The initial cost of the ROTE vehicles, including purchase and shipping cost but not import duty, would range from $11,000 to $14,000. Annual operating costs, including depreciation, maintenance, and operator salaries, would range from 40 to 65 percent of the initial cost. Annual mileage is estimated at 28,650 miles. Table 3, page 17, described how this figure was obtained.

Feasibility of the concept was judged on (a) whether or not the vehicles could be operated profitably by both shippers (or passengers) and operators and (b) whether or not the minimal road would offer more miles of road/unit of investment than existing all-weather roads.

On the basis of estimated vehicle revenue, the vehicles appear feasible to operate. That is, the revenue would be sufficient (in nearly all cases) to cover all operating costs and provide varying amounts (0 to 180 percent of the operating costs) for management overhead.

The minimal road as defined also appears feasible. That is, 23 times more miles of all-weather minimal roads can be constructed than miles of conventional all-weather roads for a given investment. Also, the annual cost/mile, including depreciation and maintenance costs, would be only about one-fifth the cost of conventional roads. However, the annual return that must be realized for a given investment is approximately three times greater for minimal roads than for conventional-road alternatives.

The favorable conclusions of the feasibility of the concept must be considered as strictly preliminary. The next appropriate action is a simulated or actual pilot test to obtain realistic field data for further evaluation.

CONCLUSIONS

On the basis of the assumptions made in this study relative to (1) cost of constructing and maintaining minimal feeder roads and (2) the purchase and other costs, annual mileage, and average speed of ROTE vehicles, the following conclusions have been reached:

(1) The remote-area transportation-system concept presented is technically and economically feasible. The system appears to be most advantageous

for situations requiring the movement of 40 tons/day or less over round-trip distances less than 100 miles.

(2) The ROTE-vehicle/minimal-road concept used as a passenger-carrying system could provide enough revenue in a typical situation to pay all vehicle operating costs as well as an additional 38 to 178 percent for management overhead.

(3) The ROTE-vehicle/minimal-road concept used as a freight-moving system could provide enough revenue in a typical situation to pay all vehicle operating costs, as well as an additional 4 to 78 percent for management overhead costs.

(4) If a given investment were available for the construction of roads, an area of approximately 23 units could be served by a minimal road installation as compared with 1 unit of area served by a conventional all-weather road. However, an annual benefit (revenue) approximately three times greater would have to be realized for the minimal-road installation than for a comparable conventional-road installation.

RECOMMENDATIONS

The following recommendations for further action are made on the basis of the study:

(1) Verify the vehicle cost and productivity information in actual or simulated pilot tests and identify required operating procedure and maintenance facilities and procedures.

(2) Verify the minimal-road costs and life estimates in actual or simulated pilot tests.

(3) Define and investigate the overall aspects of the system that are related to this transportation concept such as fuel and spare-parts distribution system, management requirements, personnel-training requirements.

CONCEPT DESCRIPTION

The characteristics of the overall concept were derived from the fixed characteristics of vehicles specified by ARPA/AGILE and the restrictions encountered in attempting to devise a low-cost road with adequate capacity. Performance characteristics of the vehicles were obtained from the vehicle manufacturers and users, and the minimal-road characteristics were based on the personal experience of the authors.

ROTE Vehicles

The three vehicles considered in evaluating this concept are shown in Figures 1, 2, and 3, and detailed information concerning them can be found in Appendix A. The tires of the three vehicles are quite similar in performance characteristics, although the diameter-to-width ratios are somewhat different. The results and advantages of using this type of tire are listed in Table 1.

TABLE 1. CHARACTERISTICS OF TIRES USED ON ROTE VEHICLES

Tire Characteristics	Result	Advantage
Large ground-contact area in relation to wheel load which provides low contact pressure	Tends to minimize vertical deformation of soil; large area to develop thrust	Reasonable power requirement; minimizes immobilizations; minimizes rut damage to roads
Carcass flexibility (minimum number of plys, low inflation pressure)	Low rolling resistance due to carcass flexure; resists punctures by conforming to (enveloping) obstacle; conforms to uneven terrain surface and large obstacles; attenuates impact when driving over uneven ground or obstacles; tire tends to deform rather than abrade on hard surface	Reasonable power requirement; tire is durable over difficult terrain; good obstacle-negotiating ability; provides relatively smooth ride without additional requirement for a suspension system; no excessive wear on hard surfaces
Large volume	Flotation for amphibious operations can be achieved entirely with tires; no need for displacement hull	Entrance and exit maneuvers in streams do not cause swamping of engine or cargo

ROTE vehicles have been designed primarily for off-road use by industrial firms. In addition to the good performance over difficult terrain, a number of other advantageous features are available. First, these vehicles have the ability to travel over conventional roads without modification. Second, most of the engine and drive-train components are very rugged, reliable, and widely used items. Third, the vehicle frames are either very simple in design or mass produced. These features make local assembly or fabrication possible.

FIGURE 1. ROLLIGON CORPORATION'S "MARSH SKEETER" VEHICLE

FIGURE 2. SHELL DEVELOPMENT COMPANY'S SHELL CRAB

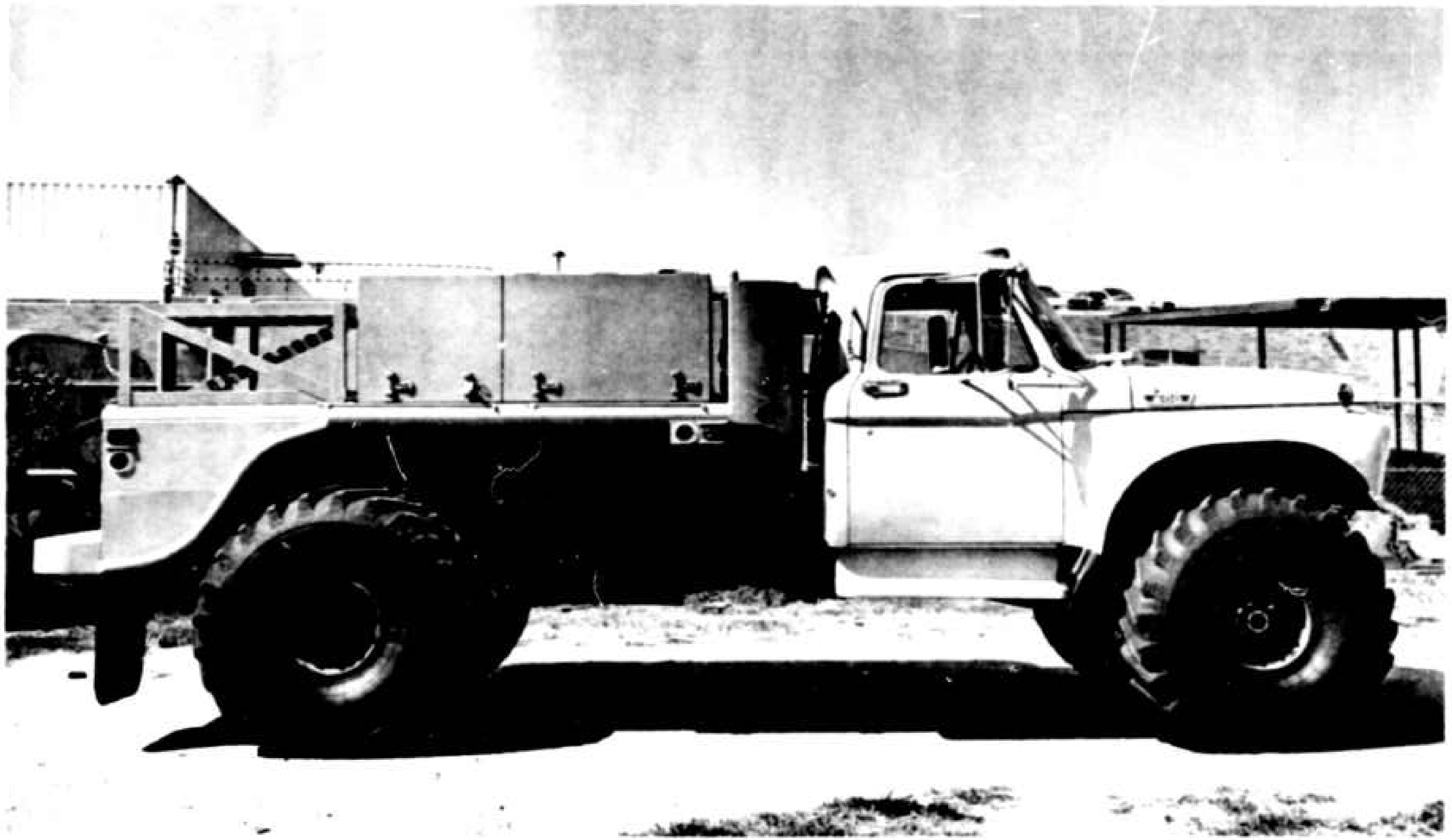

FIGURE 3. SHELL DEVELOPMENT COMPANY'S MODIFIED FORD F-600

Minimal Roads

Required Capacity

Very little information is available pertaining specifically to the volume of traffic handled by the feeder roads in remote areas. However, the capacity can be deduced by examining the information available for better-quality conventional roads.

The traffic volume on the arterial roads and highways of remote areas may range from 100 to 1500 vehicles per day. These arterial roads serve the major population centers and provide transportation for raw materials and produce moving out from the remote areas and manufactured goods from the larger metropolitan centers moving into the remote areas. Trucks and buses constitute 75 to 90 percent of the traffic on the main roads and could be expected to account for the majority of motorized traffic on the feeder roads.

The roads in remote areas can be categorized by quality and capacity as follows:

(1) Primary Roads. High-standard, all-weather quality capable of handling over 500 vehicles (truck, bus, car) per day; high-type bituminous or concrete surface

(2) Secondary Roads. Light-duty, limited all-weather quality capable of handling 100 to 500 vehicles per day; low-type bituminous, stabilized earth, or well-compacted-earth or gravel surface

(3) Feeder Roads. Light-duty, fair-weather quality handling less than 100 vehicles per day; compacted-earth surface

(4) Local Trails. Dry-weather, low quality capable of handling only small volumes of conventional traffic; natural earth surface.

The payloads of the vehicles operating on these roads range from 2,000 to 25,000 lb, depending on truck size and road type and condition. These figures, although far from being conclusive, indicate an order of magnitude of the performance which might be expected of remote-area feeder roads.

Accordingly, the maximum capacity of the ROTE-vehicle/minimal-road concept has been set at 40 tons/day past any point. This would mean a ROTE-vehicle traffic volume of 15 to 25 vehicles per day.

Required Construction Operations

The required construction operations were specified on the basis of the expected ROTE-vehicle traffic volume and an estimate of possible terrain and topography situations. Three basically different minimal-road construction operations were found necessary:

Minimal Road Type	Construction Operation
I	Improvement of existing paths or trails
II	Establishment of roads through virgin areas by clearing surface vegetation and using the natural earth surface as the roadway
III	Establishment of roads through virgin areas by clearing surface vegetation and performing a minimum amount of cut-and-fill operations.

In most developing countries with tropical climates of definite dry and rainy (monsoon) seasons, laterite soil is the predominant road-building material. Laterite is a general term denoting a class of tropical soils of complex origin which vary markedly from one place to another in composition, texture, and physical characteristics. The main advantage of a laterite-soil surface for a minimal road is that in most areas the laterite material is directly on the surface or just below the existing topsoil. This means that very little clearing and excavation are usually required during construction. Some compacting, shaping, and grading of the laterite surface is desirable to facilitate drainage and to provide a relatively smooth riding surface. If the laterite-soil road surface has a high gravel content, it is easily maintained throughout all seasons of the year, providing drainage is proper and the roadway is not inundated. However, if the laterite surface material has a relatively high clay content, the roadway surface becomes very slippery and easily rutted by traffic in the rainy season.

Conventional vehicles cause considerable wear of a laterite roadway surface (in some instances, as much as 2 inches per year). This wearing of the laterite surface results in a very hazardous dust-formation problem during dry weather. However, the basic characteristics of the ROTE vehicle, such as low bearing pressures and good mobility under extreme conditions of terrain and weather, minimize the disadvantages of minimally prepared laterite roadway surfaces.

A detailed description of the construction operations for the three minimal-road types is provided in Appendix B.

FEASIBILITY STUDY

Concept Application

A meaningful preliminary evaluation of this remote-area transportation-system concept requires the identification of a specific location because the variations in road and vehicle costs from one location to another limit the usefulness of average values. ARPA/AGILE and United States Agency for International Development (AID) were consulted for suggestions of remote locations that had a requirement for such transportation. On the basis of needs identified and the availability of pertinent information required for an evaluation, an area of northeast Thailand was selected. This area is the northeast province of Sakon Na Khon (Sakol Nakorn) (Figure 4). The need is for transportation and communication links from the district administrative centers to the provincial capital or to existing all-weather roads leading to the capital (Figure 5).

A more detailed discussion of the geographical characteristics and potential use of a ROTE-vehicle/minimal-road system can be found in Appendix C.

Road Construction and Maintenance Costs

The actual road-construction cost figures used in this analysis were derived by examining the composition and magnitude of conventional-road construction costs in developing countries. The derivation is described in Appendix D.

The road costs derived for the three types of minimal roads are shown in Table 2.

TABLE 2. MINIMAL-ROAD CONSTRUCTION COSTS

Road Type	Cost/Mile, dollars
I	0 to 800
II	1,400
III	2,000 to 5,000

Road maintenance equipment for a minimal-roadway network could consist of a grader to perform the surface grading and tools for shaping and ditch cleaning and shaping. A number of manual laborers would be needed to perform such roadside maintenance tasks as culvert cleaning and surface patching. In addition to the grader operator, who would have to be quite skilled, a crew supervisor would be needed. The cost of this maintenance is estimated at $300/mile per year.

Cost of Example Road Segments. Three possible locations for minimum roads in the Sakon Na Khon Province have been developed as examples. Because specific locations were selected, the estimate of road costs is quite realistic for a study of this type.

Example I. The first example is a minimal road from Amphur Ban Akat to Route 26 at Ban Phok Noi (Figure 6). At the present time there is an animal-cart path between the two villages that averages from 5 to 8 feet in width. The terrain is nearly level, and the path traverses numerous rice fields which undoubtedly means that the path is inundated during periods of the rainy season and provides little, if any, means of transportation. The land that is not being utilized for rice fields is covered with trees or brushwood.

The total length of the path is 21.3 miles. Of this, 1.9 miles are village streets that are 16 feet or more in width and constructed of a good loose surface material.

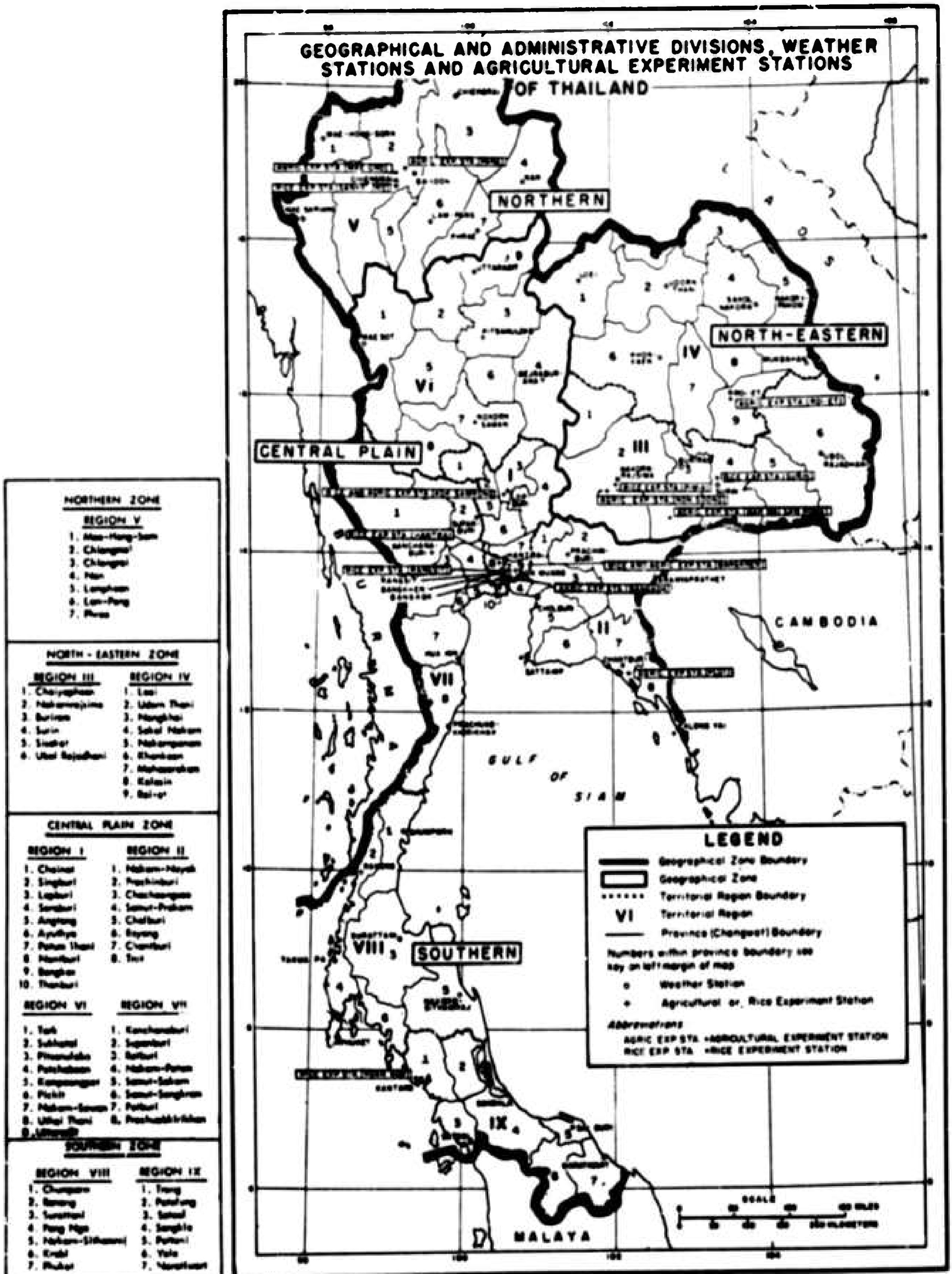

FIGURE 4. TERRITORIAL AND PROVINCIAL DIVISIONS OF THAILAND[9]

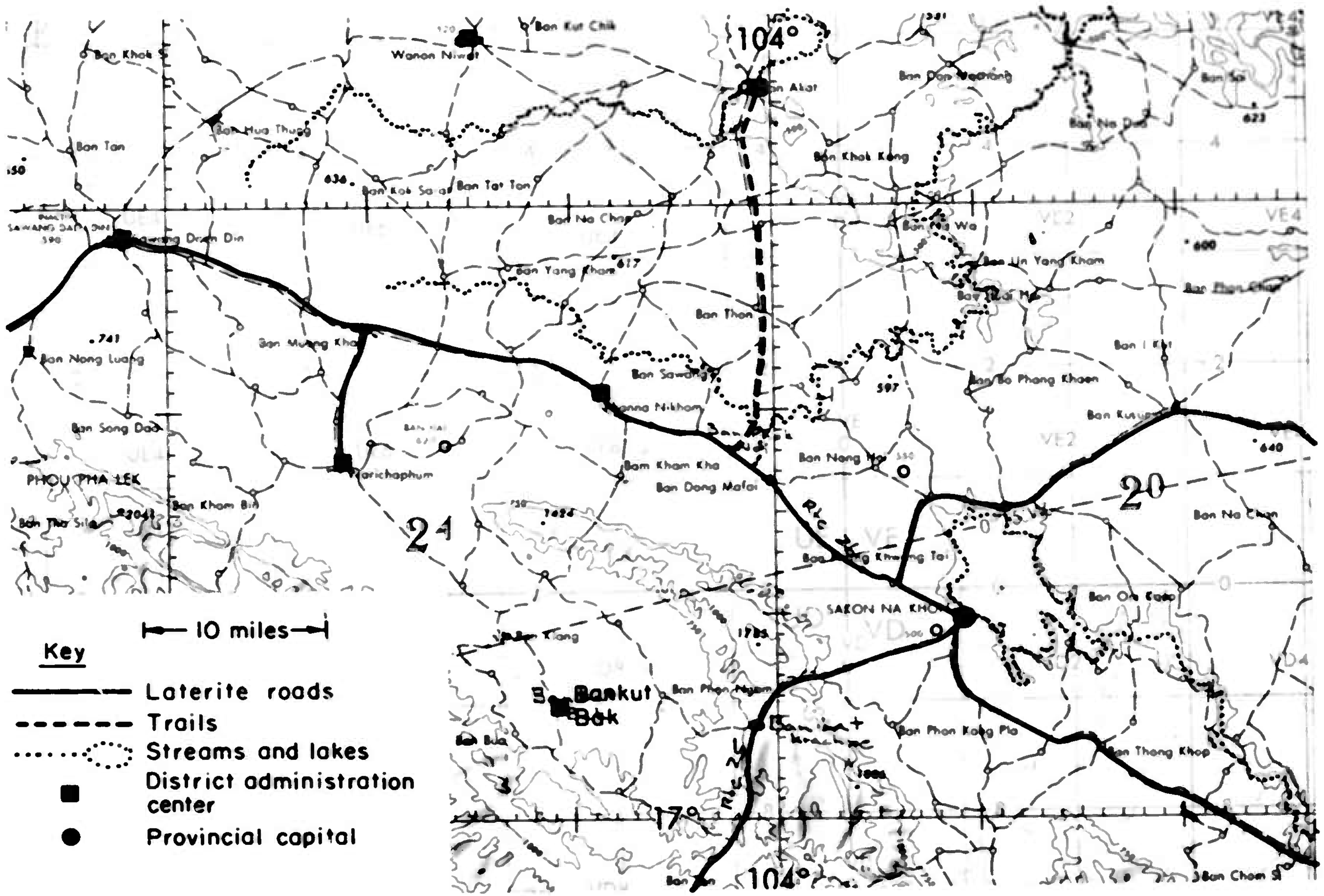

FIGURE 5. SAKON NA KHON PROVINCE

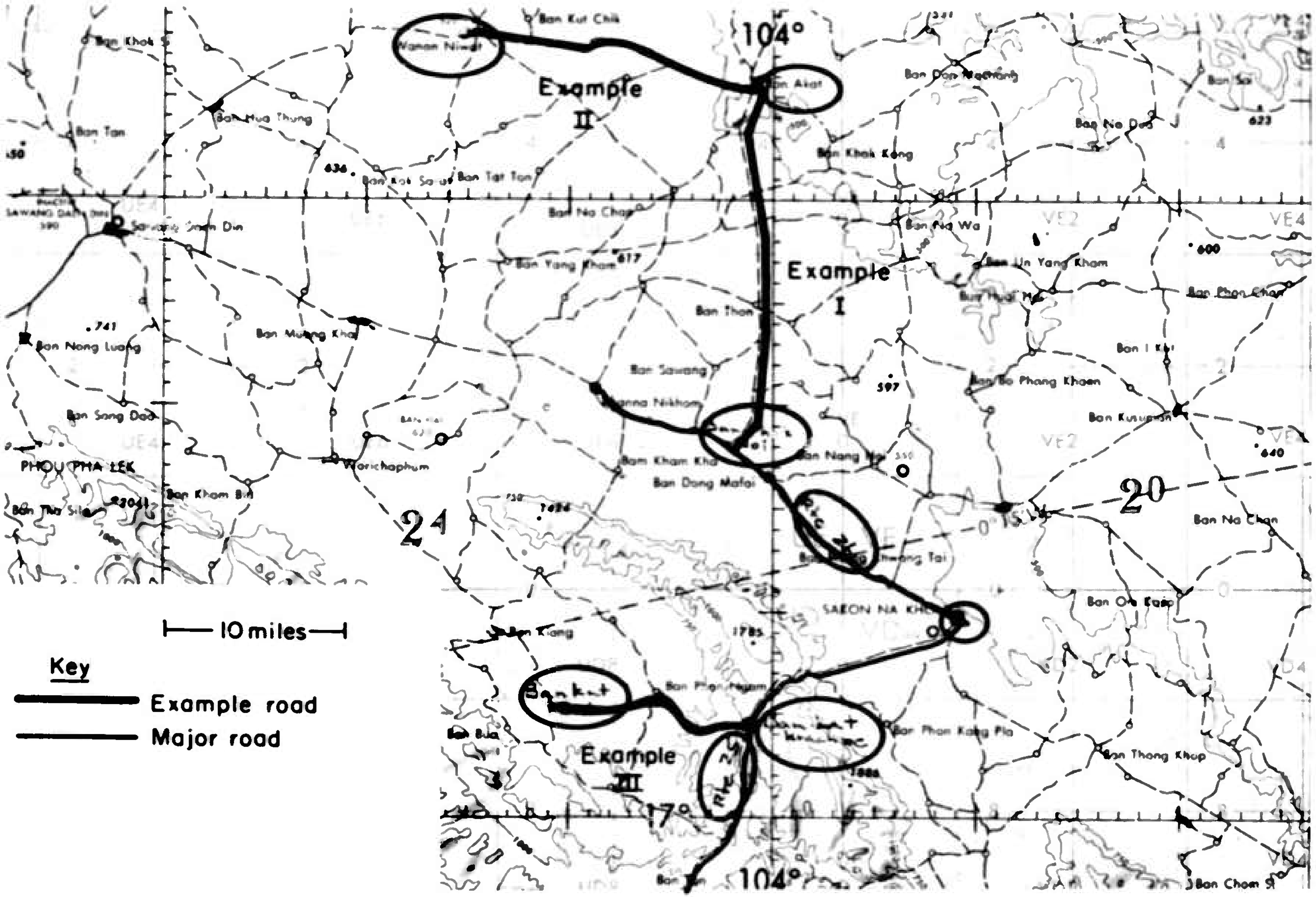

FIGURE 6. EXAMPLES OF MINIMAL ROADS

These streets would not have to be improved to accommodate ROTE vehicles. Approximately 4 miles of the path appears to go through rice fields. Probably Type III minimal-road construction would be required. The remaining sections of the path, totaling 15.4 miles, traverse woodland areas and the edges of rice fields and would require Type I minimal-road construction. Because of the proximity of the rice fields and the levelness of the terrain, the relative amount of clearing required would be less than in most wooded areas.

The construction costs for this road segment would be as follows:

Road Type	Cost/Mile	Miles	Cost
I	$ 600	15.4	$ 9,240
III	4,000	4	16,000
		Total	$25,240

Example II. Example II is a minimal road from Amphur Ban Akat westward to Amphur Wanon Niwat (Figure 6). Presently, there is an animal-cart path between the two villages similar to the one described in Example I. The terrain in this area is slightly rolling toward the middle section of the path with maximum grades of about 3 percent. The terrain on either end of the path is fairly level. Some sections of the path traverse rice fields, but most of the path crosses terrain covered with trees or brushwood.

The total length of the path is 16 miles. Of this total, 1 mile is village streets and will not have to be improved to accommodate ROTE vehicles. Approximately 4 miles of the path appear to go through rice fields. These sections of the road will probably require the Type III minimal-road construction. The remaining 11 miles traverse the woodland areas and will require Type I minimal-road construction. The slightly rolling terrain may require more extensive clearing than that required for Example I.

The costs of this road segment are as follows:

Road Type	Cost/Mile	Miles	Cost
I	$ 700	11	$ 7,700
III	4,000	4	16,000
		Total	$23,700

Example III. Example III is a minimal road from Amphur Ban Kut Bak to Route 25 at Ban Lat Krachoe. Presently, there is an animal-cart path between the two villages. The terrain in the area is quite level along the first half of the path; however, the latter part of the path is quite hilly (elevations vary from 200 meters to 340 meters) where slopes of nearly 10 percent are common. Also, there are several major streams that have to be crossed. Most of the area is covered with trees or brushwood with a few rice fields scattered randomly along the path.

The total length of the path is 13 miles. Of this total, 1/2 mile is village streets and will not have to be improved to accommodate ROTE vehicles. Only 1/2 mile goes through rice fields; this will probably require Type III minimal-road construction using the dike method to widen the path. The remaining 12 miles traverse primarily the hilly wooded terrain and will require the most extensive Type I minimal-road construction.

The construction costs for this road segment are as follows:

Road Type	Cost/Mile	Miles	Cost
I	$ 800	12	$ 9,600
III	4,000	0.5	2,000
		Total	$11,600

Average Cost for Three Examples

The average cost of the 46.9 miles of road for the three examples is $1300/mile. The annual maintenance costs are estimated to be $300/mile.

Vehicle Operating Costs

A number of factors influence the magnitude of the various unit costs that are commonly used to appraise the performance of a vehicle. Some of these factors can be determined only by experience; others are dependent on the particular application.

The payload, vehicle life, maintenance requirements, and fuel consumption used in this study were derived from the experience of two commercial concerns that have used these vehicles. The vehicle cost, operating envelope, fuel cost, and operator salary are dependent upon the particular situation. For this study they were based on the best information available for the Sakon Na Khon area.

The initial vehicle costs used in this study include applicable overseas shipping costs. Fuel costs ($0.40/gal for gasoline, or $0.25/gal for diesel fuel) are based on the current costs to users in this area. The annual mileage that could be traveled by the vehicles would depend on the speed that could be achieved, the number of hours of operation each day, and the days of operation per year. A maximum average speed of 20 mph was selected at the speed the ROTE vehicles could travel over minimal roads in good to excellent condition. During seasons of heavy rainfall, the average maximum speed would be reduced. The annual mileage estimate is based on expected road surface conditions (Table 3). Surface conditions are probably influenced primarily by local rainfall. The estimate of the daily mileage (operating time) of the ROTE vehicles is based on the frequency and probable length of stops. With villages spaced every 5 to 8 miles apart, it is estimated that the vehicles would have approximately 5 hours of operating time during an 8 to 10-hour working day.

For this estimated input data the yearly cost, the cost/mile and the cost/cargo ton-mile were computed (Table 4).

TABLE 3. ANNUAL MILEAGE ESTIMATES FOR ROTE VEHICLES

Days of Operation	Estimated Avg. Vehicle Speed, mph	Hours of Operation per Day[(a)]	Miles
244	20	5	24,400
40	15	5	3,000
25	10	5	1,250
Total 309		1545	28,650

(a) 5 hours of engine running time for an 8 to 10-hour working day.

To provide for comparisons between ROTE vehicles and other approaches a similar approach was taken to compute costs for a conventional truck on a fair-weather road and of a conventional truck on an all-weather light-duty road. These estimates are also shown in Table 4.

Potential Usefulness of the ROTE-Vehicle/Minimal-Road Concept

The real utility of the concept will depend on its effectiveness as an aid for government organization's programs and activities and its acceptance by private organizations and individuals. It was assumed in this study that the concept would be both effective and accepted.

Assuming acceptance by private organizations and individuals is somewhat speculative, but there is some evidence the remote-area populations will respond enthusiastically if such facilities are available. Dr. L. W. Huff gave the following report on the results of road-development activities in northeast Thailand which cites some encouraging examples:

> "... Villagers in one area of Northeast Thailand seem to be genuinely enthusiastic about the new roads, usually for very practical reasons. Rice and other products can be shipped to market when prices are high; indeed, the roads often bring the news that prices are high or low in the first place. One villager spoke of the past practice (and necessity) of people in his village to take rice to market by ox-cart, a 40 kilometer trip which requires about 48 hours. Upon arrival, they were at the mercy of buyers who knew the villagers would accept a low price rather than take their loads back home. The availability of roads and trucks has changed this situation. The farmer now has somewhat greater confidence in his ability to cope with what had heretofore been a rather unyielding market. At Ban Na Khu farmers remember that two years ago there were times when they could not get their rice to market at all. They also recall having to take three baht (15 cents) per tang of rice [~20 lb]; now they can get up to seven baht (35 cents) per tang by shipping in quantity on trucks when the market is at its peak.

TABLE 4. VEHICLE OPERATING COSTS

	Marsh Skeeter				Shell Crab				Ford F-600		Conventional Truck (Diesel Engine) on Fair-Weather Road		Conventional Truck (Diesel Engine) on Light-Duty, All-Weather Road	
	Gasoline Engine		Diesel Engine		Gasoline Engine		Diesel Engine		(Gasoline Engine)					
Weights														
Payload, lb	2,000		2,000		4,000		4,000		6,000		8,000		10,000	
Curb weight, lb	3,100		3,100		4,900		4,900		6,100		6,300		8,000	
Gross vehicle weight, lb	5,100		5,100		8,900		8,900		12,100		4,300		18,000	
Operating Characteristics														
Average daily engine operating time, hr/day	5		5		5		5		5		5		5	
Yearly engine operation time, hr	1,545		1,545		1,545		1,545		1,545		1,050		1,545	
Distance traveled by vehicle, miles/yr	28,650		28,650		28,650		28,650		28,650		20,480		46,500	
Fuel consumption by vehicle, gal/hr	3		2.5		4.25		3.5		5.5		5		6	
Costs														
Initial vehicle cost at location, dollars	11,576		12,076		13,260		13,760		11,330		8,000		10,000	
Depreciation rate (5-yr life), $/yr		2,315		2,415		2,650		2,750		2,266		1,600		2,000
Fuel costs, $/hr and $/yr	1.20	1,854	0.63	973	1.70	2,625	0.88	1,360	2.20	3,399	1.25	1,313	1.50	2,318
Maintenance costs, $/hr and $/yr	0.60	927	0.60	927	0.65	1,005	0.65	1,004	0.70	1,082	0.30	315	0.30	164
Vehicle operating costs (without operator) (at 5-hr day), $/hr and $/yr	1.80	2,781	1.23	1,900	2.35	3,630	1.53	2,364	2.90	4,481	1.55	1,628	1.80	2,782
Operator costs, $/hr and $/yr	0.20	618	0.20	618	0.20	618	0.20	618	0.20	618	0.20	618	0.20	618
Total costs,														
$/yr		5,714		4,933		6,898		5,732		7,365		3,846		5,400
$/mile		0.199		0.172		0.241		0.200		0.257		0.188		0.116
$/cargo ton-mile		0.199		0.172		0.120		0.100		0.085		0.047		0.028

"...(The Thailand government undertook) to build 35 kilometers of road to connect the village (Ban Akat) with the main Sakol Nakorn-Udorn highway at Amphur Phannanikom,...the bus/truck traffic increased so much on the Akat-Phannanikom road that fares dropped from 10 baht (50 cents) to seven baht (35 cents)."

Use of Concept by Law-Enforcement Agencies

The concept could be used to advantage by law-enforcement agencies for the expeditious movement of personnel to critical areas. A 2000-pound-payload ROTE vehicle would probably be the most practical and could serve as a personnel carrier and mobile communications center as suggested in the sketch in Figure 7. The limited scope of this study precludes any estimate of the cost effectiveness of such a vehicle, but it is believed that the utility of the smaller ROTE vehicles would enhance such operations.

Use of Concept as Passenger Transportation

An appropriate passenger-transportation capability in remote areas can do much to improve development and minimize development expense. It can bring people to centralized markets, medical facilities, educational centers, and agricultural demonstration areas. The use of ROTE vehicles as passenger-carrying vehicles is suggested in Figures 8, 9, and 10.

There is some information available on passenger rates for the area near Sakon Nakhon, and this coupled with the vehicle operating costs provides a rough estimate of the feasibility of these vehicles operated in this mode.

The rates which appear reasonable for 12 to 25-mile one-way trips in the area of Sakon Na Khon are $0.0238/mile/passenger over lightly traveled routes and $0.0167/mile/passenger over heavily traveled routes. The passenger capacity of the ROTE vehicles was estimated and possible revenues computed. The results are tabulated in Table 5.

Use of Concept for Freight Hauling

Remote areas often require some capability to move various types of freight. This may include agricultural produce, wood, or other natural resources or incoming manufactured goods. The ROTE vehicles could be operated in this mode as suggested by Figures 11 and 12.

An estimate of the feasibility for this operating mode for the area near Sakon Na Khon was derived from information on the possible price increase that might be obtained by the timely shipping of rice to the market.

Depending on margin (price increase), shipping distance, and vehicle used, an individual shipper could realize some profit as tabulated in Tables 6, 7, and 8.

FIGURE 7. ARTIST'S CONCEPTION OF SECURITY POLICE VEHICLE

FIGURE 8. ARTIST'S CONCEPTION OF PASSENGER VEHICLE - 10-PERSON CAPACITY

FIGURE 9. ARTIST'S CONCEPTION OF PASSENGER VEHICLE - 20-PERSON CAPACITY

FIGURE 10. ARTIST'S CONCEPTION OF PASSENGER VEHICLE - 30-PERSON CAPACITY

TABLE 5. RCTE VEHICLES OPERATING AS PASSENGER CARRIERS

Vehicle	Number of Passengers per Vehicle	Fare per Passenger-Mile, $	Total Revenue, $/mile	Vehicle Operating Cost, $/mile	Revenue Available for Management Overhead, Profit, Etc. (66 Percent of Vehicle Operating Cost, Normal)	
					($/Mile)	Percent of Operating Cost
Marsh Skeeter	10	0.0238	0.238	0.172	0.066	38.4
	10	0.0167	0.167	0.172	Cost exceeds revenue	
Shell Crab	20	0.0238	0.476	0.200	0.276	138
	20	0.0167	0.334	0.200	0.134	67
Ford F-600	30	0.0238	0.714	0.257	0.457	178
	30	0.0167	0.601	0.257	0.344	134

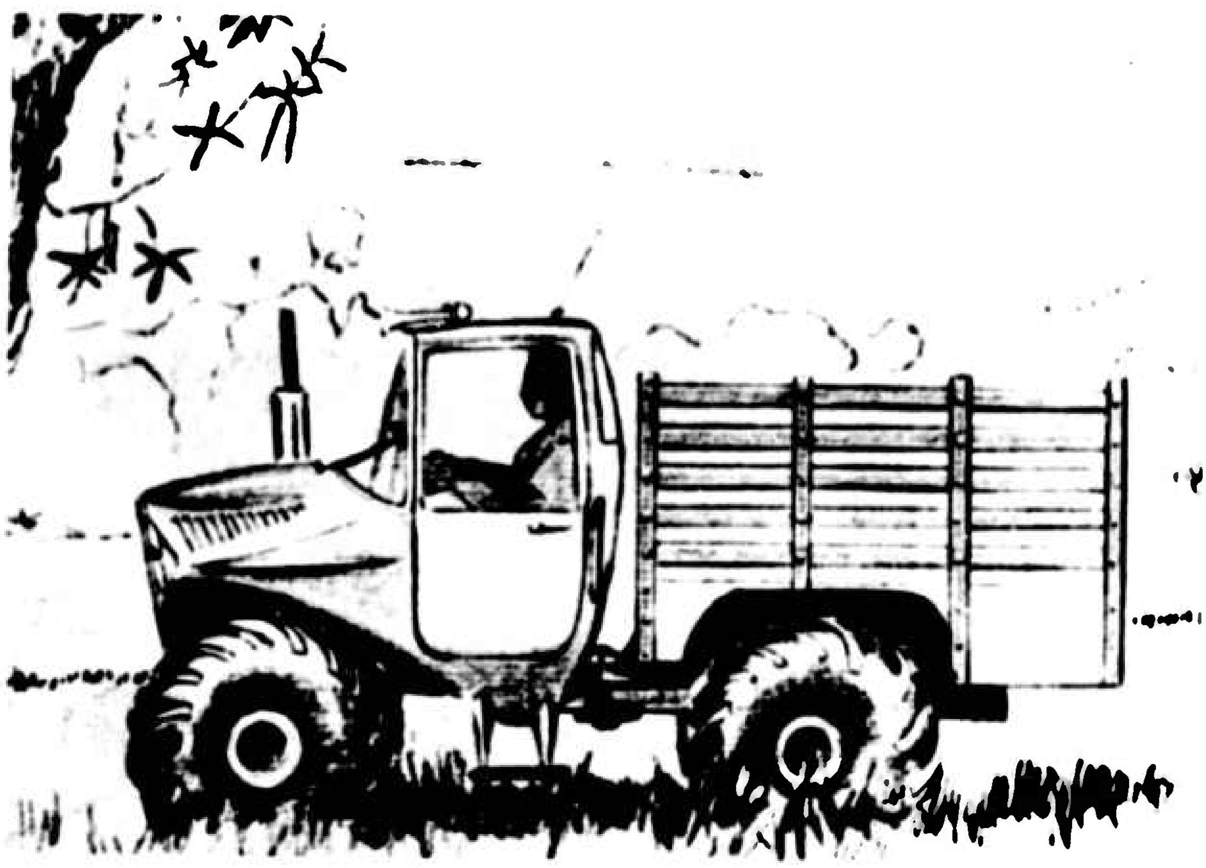

FIGURE 11. ARTIST'S CONCEPTION OF FREIGHT VEHICLE – 2000-LB PAYLOAD

FIGURE 12. ARTIST'S CONCEPTION OF FREIGHT VEHICLE - 6000-LB PAYLOAD

TABLE 6. ROTE VEHICLES AS FREIGHT CARRIERS (ROLLIGON CORPORATION'S MARSH SKEETER)

								Distribution of Increase				
								To Vehicle				
									Available for Freight Company Overhead, Profit, Etc.		To Shipper	
Margin, $/ton	Round-Trip Mileage	Vehicle Cost (Full Load Forward, Return Empty) $/mile	Vehicle Cost $	Base Value of Rice Without Benefit of Shipping by Truck $/ton	Base Value $/load	Increase in Value of Rice With Shipping (Margin) $/ton	Increase $/load	Vehicle Operating Costs, $	33 Percent of Operating Costs, $	66 Percent of Operating Costs (Normal), $	Amount, $	Percent of Base Value
5.00 (Low)	20	10 miles at 0.172	1.72									
		10 miles at 0.155	1.55 3.27	15.00	15.00	5.00	5.00	3.27	1.08		0.65	4.3
10.00 (Medium)	20	As above	As above	15.00	15.00	10.00	10.00	3.27		2.16		14.4
15.00 (High)	20	As above	As above	15.00	15.00	15.00	15.00	3.27		2.16	4.57	30.3
5.00 (Low)	50	25 miles at 0.172	4.30									
		25 miles at 0.155	3.88 8.18	15.00	15.00	5.00	5.00	Cost exceeds benefit				
10.00 (Medium)	50	As above	As above	15.00	15.00	10.00	10.00	8.18	2.70	Benefit doubtful		
15.00 (High)	50	As above	As above	15.00	15.00	15.00	15.00	8.18		5.40	1.42	9.5

TABLE 7. ROTE VEHICLES AS FREIGHT CARRIERS (SHELL DEVELOPMENT COMPANY'S SHELL CRAB)

Margin, $/ton	Round-Trip Mileage	Vehicle Cost (Full Load Forward, Return Empty) $/mile	Vehicle Cost (Full Load Forward, Return Empty) $	Base Value of Rice Without Benefit of Shipping by Truck $/ton	Base Value of Rice Without Benefit of Shipping by Truck $/load	Increase in Value of Rice With Shipping (Margin) $/ton	Increase in Value of Rice With Shipping (Margin) $/load	Distribution of Increase: To Vehicle: Vehicle Operating Costs, $	Distribution of Increase: To Vehicle: Available for Freight Company Overhead, Profit, Etc.: 33 Percent of Operating Costs, $	Distribution of Increase: To Vehicle: Available for Freight Company Overhead, Profit, Etc.: 66 Percent of Operating Costs (Normal), $	Distribution of Increase: To Shipper: Amount, $	Distribution of Increase: To Shipper: Percent of Base Value
5.00 (Low)	20	10 miles at 0.20	2.00									
		10 miles at 0.19	1.90 3.90	15.00	30.00	5.00	10.00	3.90		2.58	3.52	11.7
10.00 (Medium)	20	As above	As above	15.00	30.00	10.00	20.00	3.90		2.58	13.52	45.2
15.00 (High)	20	As above	As above	15.00	30.00	15.00	30.00	3.90		2.58	23.52	78.4
5.00 (Low)	50	25 miles at 0.20	5.00									
		25 miles at 0.19	4.75 9.75	15.00	30.00	5.00	10.00	9.75	Benefit doubtful			
10.00 (Medium)	50	As above	As above	15.00	30.00	10.00	20.00	9.75		6.44	3.81	12.7
15.00 (High)	50	As above	As above	15.00	30.00	15.00	30.00	9.75		6.44	13.81	46.1

TABLE 8. ROTE VEHICLES AS FREIGHT VEHICLES (SHELL DEVELOPMENT COMPANY'S MODIFIED FORD F-600 TRUCK)

Margin, $/ton	Round-Trip Mileage	Vehicle Cost (Full Load Forward, Return Empty) $/mile	Vehicle Cost (Full Load Forward, Return Empty) $	Base Value of Rice Without Benefit of Shipping by Truck $/ton	Base Value of Rice Without Benefit of Shipping by Truck $/load	Increase in Value of Rice With Shipping (Margin) $/ton	Increase in Value of Rice With Shipping (Margin) $/load	Distribution of Increase: To Vehicle: Vehicle Operating Costs, $	Distribution of Increase: To Vehicle: Available for Freight Company Overhead, Profit, Etc.: 33 Percent of Operating Costs, $	Distribution of Increase: To Vehicle: Available for Freight Company Overhead, Profit, Etc.: 66 Percent of Operating Costs (Normal), $	Distribution of Increase: To Shipper: Amount, $	Distribution of Increase: To Shipper: Percent of Base Value
5.00 (Low)	20	10 miles at 0.257	2.57									
		10 miles at 0.244	2.44 5.01	15.00	45.00	5.00	15.00	5.01		3.30	6.69	14.9
10.00 (Medium)	20	As above	As above	15.00	45.00	10.00	30.00	5.01		3.30	21.69	48.2
15.00 (High)	20	As above	As above	15.00	45.00	15.00	45.00	5.01		3.30	36.69	81.5
5.00 (Low)	50	25 miles at 0.257	6.43									
		25 miles at 0.244	6.10 12.53	15.00	45.00	5.00	15.00	12.53	Benefit doubtful			
10.00 (Medium)	50	As above	As above	15.00	45.00	10.00	30.00	12.53		8.28	9.19	20.4
15.00 (High)	50	As above	As above	15.00	45.00	15.00	45.00	12.53		8.28	24.19	53.6

Comparison of Minimal- and Conventional-Road Investment and Return

From the planning viewpoint it is desirable to know what advantages could be gained by investing a given amount of money in a minimal road as compared with a conventional road.

Assuming the ROTE-vehicle/minimal-road concept can provide sufficient capacity to meet the demand, the two approaches can be compared on the basis of construction and maintenance costs. The cost figures used are as follows:

(1) The minimal road costs an average of $1300/mile to construct and an average of $300/mile/yr to maintain and has a 3-year life.

(2) The all-weather conventional road costs $30,000/mile to construct and $2000/mile/year to maintain and has a 15-year life.

The ratio of miles of road or areas served (for a given investment, A) is simply the ratio of construction costs, i.e.:

$$\frac{\text{Miles of minimal road}}{\text{Miles of conventional road}} = \frac{\frac{A}{1300}}{\frac{A}{30,000}} = \frac{30,000}{1300} = 23.1.$$

The ratio of maintenance costs/mile/yr is:

$$\frac{\text{Maintenance cost for conventional road}}{\text{Maintenance cost for minimal road}} = \frac{2000}{300} = 6.7.$$

If the ratio of annual revenues (or benefit if the effect cannot be quantified in monetary terms) required for return on investment is computed, the relative merits of the two approaches are somewhat less than above.

For example, with a given investment, A, a minimal road would require an annual return (benefit) of 0.61A [i.e., depreciation (0.33A/yr) + maintenance (0.23A/yr) + interest (0.05A/yr) = 0.61A]. A conventional all-weather road would require annual return (benefit) of 0.19A. [i.e., depreciation (0.07A/yr) + maintenance (0.07A/yr) + interest (0.05A/yr) = 0.19A/yr].

The ratio of return (benefit) is then

$$\frac{\text{Annual return (benefit) for minimal road (for an investment, A)}}{\text{Annual return (benefit) for conventional road (for an investment, A)}} = \frac{0.61A}{0.19A} = 3.21.$$

However, the area served by the minimal roads is 23.1 times larger, and the larger required return (benefit) could probably be realized.

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APPENDIX A

VEHICLE CHARACTERISTICS

APPENDIX A

VEHICLE CHARACTERISTICS

Specifications of Rolligon Corporation's Four-Wheel-Drive Marsh Skeeter, Model 4450

Terrain: fully amphibious
Payload: 2000 lb maximum
Curb weight: 3100 lb
G. V. W. 5100 lb
Turning Radius: 19 feet
Tires: Four Rolligon 40 x 50 cleated bags, all powered
Ground bearing pressure: Empty 1.4 psi
Loaded 1.8 psi
Ground bearing area: 2800 sq inches (700 sq inches per tire)
Frame: steel construction, articulated
Steering: Hydraulic power steering
Width, overall: 9 ft 11-1/2 in.
Length, overall: 13 ft 0 in.
Height, overall: 6 ft 1 in.
Wheel base: 100 in.
Cargo deck: Height 43 in.
Area 31 sq ft
Width 6 ft 1 in.
Length 5 ft 1 in.
Engine: Ford Model 172, 4 cylinder, watercooled, 172 cu in. displacement, develops 68 hp at 2800 rpm. Engine is governed at 2400 rpm producing 65 hp.
Instruments: ammeter, oil pressure gauge, hourmeter, water temperature gauge
Electrical system: 12 volt
Transmission: 4 speeds and reverse, manual shift
Axles: Model 70 Spicer with no spin differentials
Brakes: on drive line, hand-lever operated
Fuel-tank capacity: 8 gallons
Winch: front mounted 8000-lb capacity
Top speed: Land 30 mph
Water 3 mph
Gradeability, percent: Forward slope 60%
Side slope 60%
Angle of approach 60°
Angle of departure 80°
Maximum height of vertical obstacle vehicle can climb: 24 inches
Cruising range: land 100 miles with 8-gallon tank
Ground clearance: 20 inches

Specifications of Shell Development Company's Shell Crab

Wheelbase: 112 inches
Wheels: Dubie Clark Manufacturing Company
Tires: 46 x 30 x 16 inches - 4-ply nylon Terra tires
Air pressure: 4 psi
Maximum width: 8 ft 0 in.
Maximum length: 14 ft 1/2 in.
Flotation: 4000 pounds
Weight of tractor: 4900 pounds
Drive: four-wheel
Power steering: four-wheel
Seats: three passenger
Axle type: NAPCO axle; formerly used on the front of a G. M. C. 2-1/2-ton 6 x 6. The axle tube on the long side cut and machined to same length as the short side making a center differential axle. All axle shafts are the same length.
Axle Ratio - 6.60 to 1.
Front axle: Front axle has a model 1-E 26 no spin differential.
Winch: Model 100 King mounted on front of tractor.
Winch Line: 125 ft of 5/16-inch 6 x 19 IPS IWRC winch line with 5/8-inch tail chain.
Brakes: Mechanical hand-brake type. The center shaft of transfer case is extended to the rear and a Jeep hand brake is installed with a standard notched brake lever serving as a vehicle brake and a parking brake.
Engine: Ford Falcon six cylinder, 170 cu in. displacement.
Maximum gross horsepower, 101 at 4400 rpm.
Bore 3.50, stroke 2.94
Cooling: Extra cooling radiator and fan installed for Ford Falcon engine.
Governor: Hoof Model K230 TA561 locked with a key.
Hourmeter: Hobbs Model MI961 MI672 switch.
Clutch: Ford Falcon 8.5-in. - 67.6 sq in.
Clutch to transmission adapter: shop made
Transmission: Warner T-9 Special P. T. O. opening on both sides. Four speeds forward, one reverse. Sliding gear selective type. Reductions, low 6.40 to 1, second 3.09 to 1, third 1.686 to 1, high-direct, reverse 7.82 to 1.
Transfer case: Napco spur gear, drop-box type. Ratio - 2 to 1.
Power takeoff: 37F7KU Tulsa with a double shaft to operate winch in front and propeller on rear.
Propeller: Evinrude Part Number 378571 - pitch 103/8 inches x 14 inches
Drive shafts: Napco
Power steering: Ford truck power steering, with a F750 pump.
Hydraulic pump: Three-position selector valve for:
(1) Front-wheel steering
(2) Four-wheel steering
(3) Oblique steering
Char-Lynn power steering sector. Dukes hydraulic cylinders.
Radio: Aluminum radio box combined with tool box.
Cap box: Aluminum cap box lined with 1/2-inch plywood and 7/8-inch felt.
Capacity: 10 caps.
Powder box: Aluminum powder box lined with 1/2-inch plywood.
Capacity: 150 pounds of powder.

Seismic cable racks: 6 breast reel hold-down racks. Seismic Seismometer jug racks.
Gasoline tanks: Two - 7-gallon marine tanks with gauge and quick couplings.
Tanks can be removed, filled, and returned.
Generator: Leece Neville 40-amp alternator.
Battery: 12-volt Auto Lite with marine battery box.

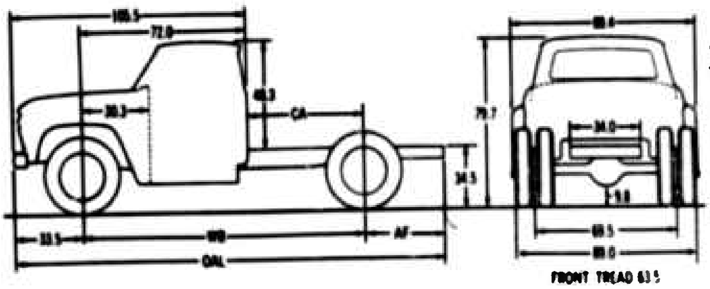
FORD TRUCKS F-600

GVW: STANDARD 17,000 LB.
MAXIMUM 24,000 LB.
GCW: MAXIMUM 32,000 LB.

Model	GVW	Minimum Equipment Required for Warranty at Indicated GVW
F600	17,000*	
F601	15,000°	
F602	20,000°	V-8 or 300 HD Six Engine
F610	21,000°	V-8 or 300 HD Six Engine, 6000-lb. Front Axle and Optional Frame
F611	22,000°	V-8 or 300 HD Six Engine, 17,000-lb. Rear Axle and Optional Frame
F612	23,000°	V-8 or 300 HD Six Engine, 6000-lb. Front Axle, 17,000-lb. Rear Axle and Optional Frame
F615	24,000°	V-8 or 300 HD Six Engine, 7000-lb. Front Axle, 17,000-lb. Rear Axle and Optional Frame

*Standard GVW rating plate. °Optional GVW rating plate available.

GCW	Minimum Equipment Required for Warranty at Indicated GCW
29,000	V-8 or 300 HD Six Engine
32,000	V-8 or 300 HD Six Engine



	Dimensions			Base Curb Weight		
WB	CA	AF	OAL	Front	Rear	Total
132	60	29.0	204.5	2825	2115	4940
144	72	29.0	216.5	2845	2130	4975
156	84	29.0	228.5	2875	2150	5025
174	102	60.5	248.0	2925	2195	5120°
194	122	73.0	200.5	2000	2270	5270

Dimensions (in.) are for base models w/standard equipment. Weights (lb.) include standard equipment, fuel, water and oil.

Add—front, rear, total (lb.):
132" wb.: 9' stake—25, 965, 990; Platform—15, 645, 660
156" wb.: 12' stake—70, 1115, 1185; Platform—50, 765, 815
For Cowl or Windshield models:
Deduct—front, rear, total (lb.): Cowls—330, 180, 510; Windshields—310, 165, 475

STANDARD EQUIPMENT

ENGINE: Ford .... 240 Six

ENGINE EQUIPMENT:
- Air Cleaner, Oil-Bath .... 1 quart
- Crankcase Emission System .... Open
- Oil Filter ..... Full-Flow Disposable-Type, 1 quart

ALTERNATOR: Autolite .... 38 amp.—570 watt

AXLE, FRONT: Ford .... 5000 lb.

AXLE, REAR: Rockwell F-106 .... 15,000 lb.
Ratio .... 6.8 to 1

BATTERY: .... 12 volt—66 plates—55 amp-hr

BRAKES, SERVICE: .... Vacuum-Hydraulic
- Front .... 14" x 2½"
- Rear .... 15" x 4"
- Vacuum Booster, Diaphragm—Dia .... 11½ in.

BRAKES, PARKING: Bendix Internal Shoe .... 9" x 2"
Location .... Rear of Transmission
(Orscheln lever w/Cowl and Windshield models.)

CAB: .... Standard Conventional

CLUTCH: .... HD 11"—123.7 sq. in.

FRAME: Single Channel .... 36,000 psi
Section Modulus—132" thru 174" wb. 9.45
194" wb. 10.64

FUEL TANK: .... 19.5-gal. Inside Cab
(18-gal. LH, outside frame w/Cowl or Windshield.)

SPRINGS, FRONT: Capacity @ Pad .... 2600 lb.

SPRINGS, REAR: .... Radius-Leaf Type
Capacity @ Pad .... 6700 lb.

STEERING: .... Gemmer 375

TRANSMISSION: .... 4-Speed Direct
Synchronized .... New Process 435

TIRES: F & DR .... Tube-Type 7.50 x 20 8PR

WHEELS: .... Six 6-Hole Disc
Rims RH5° .... Six 20 x 6.0

ADDITIONAL STANDARD EQUIPMENT:
- Ammeter and Oil Pressure Gauge
- Bumper, Front—Channel
- †Dome Light
- †Door Locks, LH and RH
- Horn, Single Electric
- *ICC Emergency Flasher
- †Mirror, LH—Non-Telescopic (Shipped loose)
- †Running Boards
- *Seat Belts, LH and RH
- Turn Signals:
  - *Double-Faced Front, Taillights Rear
  - Switch, Lever and Wiring—Cowl Models
- *Windshield Washers
- *Windshield Wipers, Dual Electric—Single-Speed

**Except Cowl models.*
†Except Cowl & Windshield models.

F-600

OPTIONAL EQUIPMENT

ENGINES: .... Ford

300 HD Six—*Includes 12" clutch.*
330 V-8—*Includes 13" clutch and velocity governor.*
330 HD V-8, 361 HD V-8—*Includes 13" clutch, Centri-vac governor and replaceable element oil filter.*

ENGINE EQUIPMENT:

Crankcase Emission System:
Required for Calif. .... Closed
Fan (N.A. w/240 Six) .... Extra Cooling
Governor .... Velocity
Ranges—Six .... 1800-3000 or 2800-3800 rpm
Radiator .... Extra Cooling‡
Tachometer .... Mechanical*
Transistorized Ignition System ..... Perma-Tuned†

**w/330 HD V-8 and 361 HD V-8 only.*
†Requires optional alternator.
‡N.A. w/300 HD Six or 361 HD V-8.

ALTERNATORS:

Autolite .... 45 amp.—675 watt
Autolite .... 55 amp.—825 watt
Leece-Neville .... 60 amp.—900 watt

AXLES, FRONT:

5500 lb. .... Ford
6000 lb. .... Ford-Rockwell
7000 lb. .... Ford-Rockwell*

**Includes 15" x 3" brakes, 3000-lb. springs and front shock absorbers.*

AXLES, REAR: .... Ratios

15,000 lb. Single-Speed
Rockwell F-106 .... 6.2, 6.8 or 7.2 to 1
15,000 lb. Two-Speed
Eaton 13802 .... 5.83/8.12 or 6.33/8.81 to 1
17,000 lb. Single-Speed*
Rockwell H-14? .... 5.83, 6.8 or 7.2 to 1
17,000 lb. Two-Speed*
Eaton 16802 .... 5.57/7.75 or 6.50/9.04 to 1

**Includes 15" x 5" brakes, 12¾" vacuum booster, 1½" master cylinder and 8100-lb. springs.*

BATTERY: .... 12 volt—66 plates—70 amp-hr

BRAKES, SERVICE:

Vacuum-Hydraulic, HD
Front: 6000-lb. axle .... 15" x 3"■
Rear: 15,000-lb. axle .... 15" x 4½"▲
17,000-lb. axle .... 15" x 6"
Air-Over-Hydraulic*‡ .... Bendix Air Pac
Full Air*

	Axle (lb.)	Cam-Type	†Wedge-Type
Front:	6000, 7000	16" x 2½"	15" x 3"
Rear:	17,000	16½" x 4½"	15" x 5"
	17,000-HD	—	15" x 6"

■N.A. w/15" x 4" rear brakes.
▲Includes 12¾" vacuum booster and 1½" master cylinder.
‡Available in same sizes as vacuum-hydraulic.
**N.A. w/240 Six. Includes 7¼ cu. ft. air-cooled compressor, air wipers and low air pressure buzzer. Includes governor w/300 HD Six. Cam and wedge brakes N.A. in mixed combinations.*
†Self-adjusting.

BRAKE EQUIPMENT:

Brakes, Parking—Rear Wheel .... Spring-Set*
Limiting Valve, Front Wheel .... Air Brakes
Vacuum Booster (w/15" x 4" brakes) ... 12¾" dia.‡
Vacuum Reserve Tank: Capacity ..... 1100 cu. in.†

**Requires full air brakes.*
†Includes vacuum gauge with low vacuum warning light.
‡Includes 1½" master cylinder.

CLUTCHES:

w/240 Six .... 12"—159.8 sq. in.
w/300 HD Six .... 13"—183.4 sq. in.

FRAMES:

Single Channel .... 36,000 psi
Section Modulus 11.84
Reinforced .... 36,000 psi
Section Modulus (w/inverted "L" reinf.) .. 18.00

FUEL TANKS: (In lieu of std.) ...... Frame-Mounted
Rectangular, LH (N.A. w/132" wb.) .... 30 gal.

SHOCK ABSORBERS: .... Front and/or Rear
(Front shock absorbers included w/7000-lb. axle.)

SPRINGS: .... Capacity @ Pad
Front w/5500 & 6000-lb. axles .... **3000 lb.**
w/6000 & 7000-lb axles .... **3300 lb.**
Rear .... Radius-Leaf Type
w/15,000-lb. axles .... **8100 lb.**
w/all axles .... **9300 lb.**
w/17,000-lb. axles .... **10,400 lb.**
Auxiliary .... **2250 lb.***

**Recommended for use with high center-of-gravity loads and/or for off-highway operation.*

STEERING, POWER: .... Linkage-Type

TIRES: .... **Tube-Type**
7.50 x 20 10PR
8.25 x 20 10PR
8.25 x 20 12PR
9.00 x 20 10PR

TRANSMISSIONS:

5-Speed
Clark 250V .... Direct-in-Fifth
Clark 251VO .... Overdrive-in-Fifth
5-Speed .... Synchronized
Clark 2653-V1 .... Direct-in-Fifth
Clark 2622-V1 .... Direct-in-Fifth
Clark 264VO .... Overdrive-in-Fifth

PRODUCTS OF Ford

FORD TRUCKS . . . BUILT TO LAST LONGER!

Form No. FDT 6630

Litho in U.S.A. 8/66

Characteristic Sheet

Ford F-600 Modified to Accept Terra Tires

Payload	6,000 pounds
Curb weight	6,100 pounds
G. V. W.	12,100 pounds

Engine 300 in.^{3}, 6-cylinder, gasoline.

APPENDIX B

CONSTRUCTION OPERATIONS FOR MINIMAL ROADS

APPENDIX B

CONSTRUCTION OPERATIONS FOR MINIMAL ROADS

Minimal Road I

In most cases of constructing a Type I minimal road the existing path would have to be widened (probable right-of-way of 20 feet) and cleared to accommodate the ROTE vehicles and the related roadway drainage facilities. Some excavation, with earth moving less than 100 yards, might be required to level the alignment of the existing path or to replace or remove poor roadway materials. Although the ROTE vehicles can traverse almost any terrain, it would be desirable to have a relatively level roadway alignment wherever feasible to facilitate ease of vehicle operation. Because of past utilization of the path with animal-drawn carts and because of the low bearing pressures associated with the large-contact-area tires, little effort should be required on the path surface. Some grading and shaping should occur to provide a crown in the path to assist in drainage and to provide a relatively smooth operating roadway surface. Drainage ditches should be constructed along both sides of the path, and in some low areas, culverts may be required to handle large rainfall runoffs in the monsoon seasons.

A dozer with blade should be utilized to perform the clearing and excavation construction operations for Minimal Road I. In addition, the dozer should assist in the construction of drainage ditches. It is estimated that a dozer could proceed at the rate of 1 mile per day performing these construction operations. This is assuming that the surface vegetation does not include any trees that could not be uprooted by the dozer. A grader should be utilized for shaping the roadway surface and to provide the finishing touches on the drainage ditches. This operation would follow the dozer operation, and it is estimated that the grader could proceed at a rate of 2 miles per day. Culverts could be placed manually wherever they are needed. Culvert installation operations should never interfere with the other roadway construction operations on this type of minimal roadway.

Minimal Road II

For the minimal roadway that is established through virgin areas by clearing surface vegetation and using the natural earth surface as the roadway surface (Minimal Road II), the construction operations will be quite similar to those explained previously for Minimal Road I. The basic difference will be that Minimal Road II will require more extensive clearing operations to provide a right-of-way wide enough (approximately 20 feet) to accommodate the ROTE vehicles and the related roadway drainage facilities. Again, because of the low bearing pressures associated with the high-contact-area tires, only a minimum compactive effort should be required on the roadway surface.

The dozer and grader will be utilized for roadway construction operations in the same manner on Minimal Road II as for Minimal Road I. However, because of the more extensive clearing operations, it is estimated that the dozer could only proceed at a rate of 1/2 mile per day.

Minimal Road III

The minimal roadway that is established through virgin areas by clearing surface vegetation and performing a minimum amount of cut and fill excavation operations (Minimal Road III) will require a relatively larger initial capital investment than the other minimal roadway types. This is because excavation operations that require earth to be moved sizable distances result in a much greater effort in manpower, equipment, and time than the other roadway-construction operations that are associated with minimally prepared roads. Minimal Road III would probably be constructed in rice paddy or swampy areas where a roadway must be defined to establish a way or direction of crossing such an area.

Minimal Road III could be constructed in two ways (Figure B-1a). One method would be to establish a roadway by removing enough material from the area to accommodate the ROTE vehicle. Dikes and drainage ditches would be established on both sides of the road to define the roadway. If the area became inundated, poles might have to be placed at selected intervals along the dikes to further define the roadway for utilization by the ROTE vehicle during the rainy season. Since the ROTE vehicle can have an amphibious capability, flooding of the adjacent swamp or rice paddy, area should provide no barrier to movement. Another method would be to establish a dike wide enough to accommodate the ROTE vehicle by using locally available material wherever possible (Figure B-1b). This type of construction must take place during the dry season since the locally available material would probably consist mostly of a wet clay. However, this clay usually dries quite readily in the sun, and it provides a fairly good subgrade material that will stand up to most adverse weather conditions with a minimum amount of compactive effort. This compaction could be provided by the ROTE vehicles utilizing the roadway and natural settlement. Again, if the dike was inundated in the rainy season, poles might have to be placed along both sides of the dike to define the roadway.

Clearing operations would not be required for this type of minimal road construction since any clearing would be covered under the cost of excavation. Culverts might be provided for the dike construction method if rapidly flowing water presented a potential roadway washout problem. In most cases, rapidly flowing water is not a problem in low-lying rice paddies or swamps. Grading and shaping operations for the dike construction method would be desirable, if at all feasible, to facilitate vehicle operation. It would undoubtedly be impossible to perform a useful grading and shaping operation in the channel construction mehtod because of water seepage problems.

A dozer with blade could be utilized under most conditions to perform the required construction operations for Minimal Road III. A tractor-scraper unit would be desirable for the channel construction method if soil conditions would support such a unit. If soil conditions would not support a dozer, manual labor might have to be utilized to construct Minimal Road III. (It requires 250 to 300 laborers working with shovels and picks to do the work of one dozer.) It is estimated that a dozer could proceed at a rate of 1/2 mile per day to perform the required construction operations under normal conditions in the dry season. If possible, a grader should be utilized to assist in the grading and shaping operation for the dike construction method.

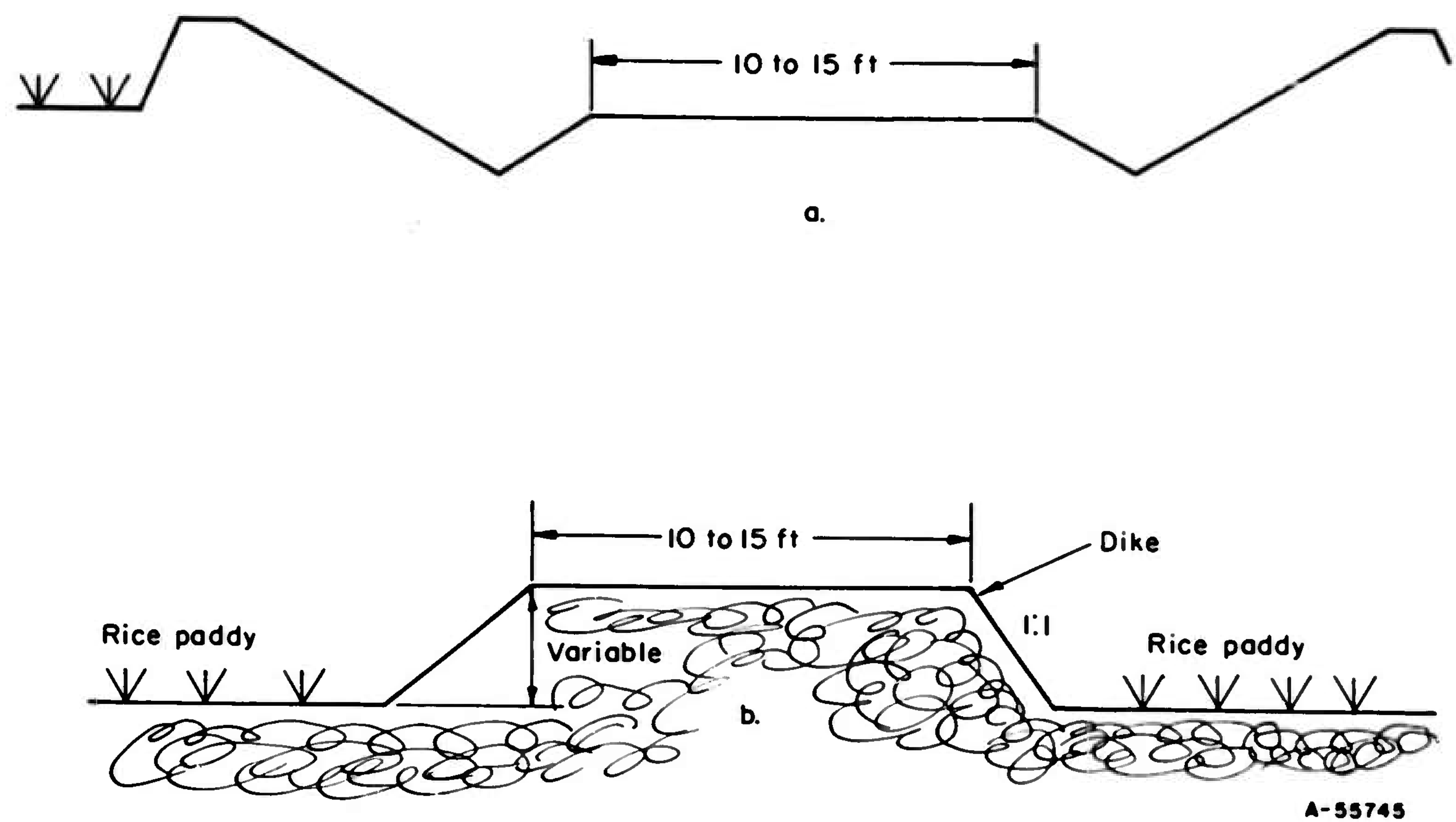


FIGURE B-1. MINIMAL ROAD CROSS SECTIONS WHERE FILL OR CHANNEL CONSTRUCTION IS REQUIRED

Minimal roads that are established in mountainous areas will have to be similar to Minimal Road I. However, extensive clearing and excavation operations in mountainous regions usually raise the roadway construction costs to a level where the type of road could no longer be considered in the minimal category. The ROTE vehicles have relatively good grade-climbing characteristics; therefore, these vehicles should have no problems traversing the majority of existing paths in mountainous areas, provided the paths are wide enough.

APPENDIX C

BRIEF DESCRIPTION OF THE GEOGRAPHICAL CHARACTERISTICS OF THE SAKON NA KHON PROVINCE OF NORTHEAST THAILAND

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BRIEF DESCRIPTION OF THE GEOGRAPHICAL CHARACTERISTICS OF THE SAKON NA KHON PROVINCE OF NORTHEAST THAILAND

The northeast region of Thailand consists of 33 percent of the available land area and contains 35 percent of the population of the country. This region has the lowest average standard of living in Thailand - $250 per person per year. The northeast has approximately 30 percent of the roads (3600 km or 2160 miles) in Thailand's highway system of which:

(1) 12 percent are primary roads

(2) 11 percent are secondary roads

(3) 77 percent are feeder and local roads.

The traffic volume (1963) on primary roads in the Sakon Na Khon Province varies from 50 to 300 vehicles per day (75 percent trucks and buses). Much of the existing system of feeder roads is simply cut trails which exist during the dry season but cannot be distinguished from the rice paddies during the rainy season.

The existing and potential transportation requirements for the Sakon Na Khon Province can be appreciated by noting the various agricultural and commercial activities that are carried on in this province and the bordering provinces. Table C-1 shows the various commodities which are important for both intra- and interprovincial trade.

The problems involved in developing a feeder-road network in this area are determined by the various topographical and climatic features of the area.

The northeast is basically a broad, upland plateau partially bordered on the west and south by relatively rugged mountains and on the north and east by the Mekong River. Generally, the surface of the northeast regions is undulatory with some small shallow lakes and occasional hill ranges. A large part of the northeast is covered with deciduous forests except along the major streams and low areas where the land is cultivated or is of a marshy nature.

The surface features of the northeast can be categorized as follows:

(1) The alluvial plains are rather pronounced river basins. The sediments in the plains are mainly clay, but lighter textured materials are found on the levees.

(2) The low terrace areas occupy a relatively higher position than the alluvial plains. The higher parts of this terrace are composed of light-textured sediments, whereas in the lower parts, heavy deposits dominate the surface layers. Rice fields normally occupy the lower parts, while forest land predominates in the higher parts.

TABLE C-1. AGRICULTURAL AND OTHER ACTIVITIES IN THE VARIOUS PROVINCES OF NORTHEASTERN THAILAND

Province	Major Crop	Secondary Crops	Other Activities: Agricultural	Other Activities: Nonagricultural	Important Articles of Trade
Sakon Na Khon	Rice	Cotton, sugarcane, chillies, cardamoms	Raising of cattle, buffaloes, pigs, silkworms; fishing	Weaving: mat and basket making; earthenware; carpentry; sawmill industry; saltmaking; goldsmith, silversmith, and blacksmith work; collecting jungle products; and trade	Rice, cattle, pigs, cardamoms, chillies, hides, and buffaloes
Kalasin	Rice	Cotton, tobacco, sugarcane	Raising of cattle, buffaloes, pigs, silkworms, stick-lac; fishing	Weaving, trade, carpentry, wood cutting, and basketmaking	Rice, raw silk, cow and buffalo hides
Udorn Thani	Rice	Tobacco, chillies, cotton, sugarcane, coconut, areca-nut, corn, beans and peas, onions, garlic, bananas, cardamoms	Raising of cattle, horses, pigs, poultry, buffaloes and silkworms; fishing	Cutting of wood, rattan, and cassia wood; manufacture of bricks, tiles, basketware, earthenware, salt, palm sugar, dammar torches and bullock carts; weaving, carpentry, blacksmith work, transport service, and trade	Rice, bullocks, buffaloes, pigs, cow and buffalo hides, silk, salt, palm sugar, molasses, cardamoms, dammar torches, wood planks, and horns
Nongkhal	Rice	Tobacco, peanuts, green gram, sugarcane, beans and peas, corn, cotton	Raising of cattle, buffaloes, horses, pigs, poultry, silkworms; fishing	Manufacture of bricks and earthenware; tile, carpentry, goldsmith and blacksmith work; collecting jungle products; basketmaking; weaving; palm sugar; dammar torches; construction of bullock carts; saltmaking, and trade	Rice, bullocks, buffaloes, pigs, hides, salt, tobacco, cotton, cassia wood, dammar, peas and beans
Nakornpanom	Rice	Cotton, tobacco, fruit and vegetable gardening, sugarcane, beans and peas, pepper, pineapples, sesame, cardamoms	Raising of cattle, buffaloes, pigs and poultry; fishing	Weaving, saltmaking, sawmill industry, trade, basketware, earthenware	Rice, cattle, buffaloes, cowhides, buffalo hides, salt and cardamons

Source: Nuttonson, M. Y., The Physical Environment and Agriculture of Thailand, American Institute of Crop Ecology, Washington, D. C. (1963).

(3) The middle terrace formations are normally undulating to rolling and are quite diverse and differ from others in that traces of the old alluvial pattern cannot be readily recognized. The upper stratum is sandy and the lower one is clayey. The transitional zone is mostly very abrupt and is often characterized by the presence of laterite gravels and rounded pebbles. Only a relatively small area of the high terrace formations remains in the Northeast. Erosion through the years has left only small "islands" higher than and surrounded by the younger terrace formations.

(4) Hill ranges, peaks, and low ridges can be observed throughout the Northeast. They are composed mainly of sandstone and conglomerate.

Alluvial soils are composed of recent, water-deposited sediments of the flat or gently sloping flood plains of the rivers and lakes. In the larger flood plains, the materials are mainly clays; but in the smaller flood plains and valleys of the interior, medium-textured sediments are more common. Coarse materials are deposited on levees of rivers, creeks, and alluvial fans in hilly areas. Fine-textured sediments are found in valley basins and lake bottoms. Drainage conditions of the alluvial soils differ greatly. Most are poorly drained and grayish. Better-drained soils, found mainly on levees and alluvial fans, are usually brownish throughout.

The rainfall of the Sakon Na Khon area is shown in Table C-2.

TABLE C-2. MONTHLY RAINFALL DATA FOR SAKON NA KHON PROVINCE

Month	1963 Rainy Days	1963 Rainfall, mm Total	1963 Rainfall, mm Heaviest in 24 Hours	1962 Rainy Days	1962 Rainfall, mm Total	1962 Rainfall, mm Heaviest in 24 Hours	Average Rainfall, mm
January	--	--	--	--	--	--	6.9
February	2	5.7	3.1	--	--	--	18.9
March	9	70.1	35.6	--	28.8	--	54.5
April	4	14.9	12.3	--	96.1	--	88.8
May	18	202.7	39.2	--	260.5	--	235.5
June	22	448.7	74.9	--	281.0	--	233.9
July	24	363.8	59.2	--	215.1	--	259.4
August	21	321.2	74.3	--	388.9	--	270.9
September	20	185.2	35.2	--	286.1	--	255.7
October	4	23.5	11.4	--	127.6	--	54.7
November	4	59.2	52.2	--	35.9	--	12.6
December	--	--	--	--	--	--	1.2

APPENDIX D

DERIVATION OF ROAD-CONSTRUCTION COSTS

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DERIVATION OF ROAD-CONSTRUCTION COSTS

Table D-1 shows the composition of road-construction costs for primary, secondary, and feeder roads. Because conditions vary greatly in different countries and areas, such a table can only be illustrative. Table D-1 is representative of average working conditions for road construction in rolling terrain with adequate subsoils and with quarries or pits of suitable road materials available at sites not more than 10 miles apart.

The construction-cost figures that are shown in Table D-2 were derived from analyzing road-construction-cost data from many developing countries with vastly different terrain and climate conditions. These figures take into account the following:

(1) Salaries of skilled and unskilled labor

(2) Cost of materials

(3) Equipment depreciation

(4) Supplies for the equipment (fuel, lubricants, repair parts, etc.)

(5) Overhead

(6) Custom duties and other taxes.

The construction-cost figures for secondary roads are actually the amount of capital needed to upgrade a feeder road to secondary-road standards. Experience in constructing primary roads in developing countries indicates that the cost of new construction is approximately the same as upgrading a secondary road to primary road standards.

Table D-3 shows typical annual roadway maintenance cost comparisons for the various types of roadways found in developing countries. As with roadway construction costs, it is very difficult to establish representative roadway maintenance costs for each type of roadway because the factors that affect the amount and type of maintenance required vary greatly from one region to another.

The cost of each type of road-construction operation in developing countries was determined by multiplying the percentage figure from Table D-1 by the total cost per mile for each type of road from Table D-2.

The cost/mile of the three minimal-road types was then computed by estimating the proportion of various construction operations required (Tables D-4, D-5, and D-6) and deriving the actual cost (Table D-7).

Tables D-4 and D-5 show the probable composition of road-construction costs for Minimal Roads I and II through remote areas in nonmountainous terrain and dry-weather conditions.

TABLE D-1. COMPOSITION OF ROAD-CONSTRUCTION COSTS

Type of Operation	Percent of Total Cost of Road per Mile		
	Feeder Road	Secondary Road	Primary Road
Clearing	3	2	2
Excavation with earth moving less than 100 yards	20	16	14
Transport of earth more than 100 yards	12	10	9
Compaction and grading	12	11	10
Production of road materials	12	10	8
Haulage of road materials	18	13	8
Mixing, spreading, and compaction of base courses	9	8	7
Road surfacing:			
Bituminous surface treatment	--	10	--
High-type bituminous	--	--	18
Drainage and masonry works (ditches, culverts, retaining walls, etc.)	8	8	8
Structures (bridges, viaducts, etc.)	6	12	16
Total	100	100	100

TABLE D-2. REPRESENTATIVE ROADWAY-CONSTRUCTION COSTS FOR THE VARIOUS TYPES OF ROADWAYS IN DEVELOPING COUNTRIES

Type of Roadway	Cost per Mile, dollars
Feeder	10,000
Secondary	25,000 to 50,000
Primary	50,000 to several hundred thousand

TABLE D-3. REPRESENTATIVE ANNUAL ROADWAY-MAINTENANCE COSTS FOR THE VARIOUS TYPES OF ROADWAYS IN DEVELOPING COUNTRIES

Type of Roadway	Cost per Mile, dollars
Feeder	800
Secondary	2,000
Primary	2,500

TABLE D-4. COMPOSITION OF ROAD-CONSTRUCTION COSTS FOR MINIMAL ROAD I

Type of Operation	Percent of Total Cost of Road per Mile
Clearing and excavation with earth moving less than 100 yards	50
Drainage and masonry works (ditches and culverts)	30
Grading and shaping	20
Total	100

TABLE D-5. COMPOSITION OF ROAD-CONSTRUCTION COSTS FOR MINIMAL ROAD II

Type of Operation	Percent of Total Cost of Road per Mile
Clearing and excavation with earth moving less than 100 yards	60
Drainage and masonry works (ditches and culverts)	30
Grading and shaping	10
Total	100

TABLE D-6. COMPOSITION OF ROAD-CONSTRUCTION COSTS FOR MINIMAL ROAD III

Type of Operation	Percent of Total Cost of Road per Mile
Excavation with earth moving less than 100 yards	94 to 100
Drainage (culverts)	0 to 3
Grading and shaping	0 to 3
Total	100

TABLE D-7. MINIMAL-ROAD CONSTRUCTION COSTS

Minimal Road	Cost per Mile, dollars
Type I	0 to 800
Type II	1,400
Type III	2,000 to 5,000

Table D-6 shows the probable composition of road-construction costs for Minimal Road III in swampy or rice paddy areas under dry-weather conditions.

Road maintenance for a minimal-roadway network could consist of a grader to perform the surface grading and shaping and ditch cleaning and shaping, a number of manual laborers to perform such roadside maintenance as culvert cleaning and surface patching, and a crew supervisor to maintain control over the maintenance work being performed. This maintenance is estimated at $300/mile per year.

TABLE D-5. COMPOSITION OF ROAD-CONSTRUCTION COSTS FOR MINIMAL ROAD II

Type of Operation	Percent of Total Cost of Road per Mile
Clearing and excavation with earth moving less than 100 yards	60
Drainage and masonry works (ditches and culverts)	30
Grading and shaping	10
Total	100

TABLE D-6. COMPOSITION OF ROAD-CONSTRUCTION COSTS FOR MINIMAL ROAD III

Type of Operation	Percent of Total Cost of Road per Mile
Excavation with earth moving less than 100 yards	94 to 100
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13. ABSTRACT

This report is a feasibility study of a remote area land transportation concept consisting of a vehicle-roadway combination. The concept description includes a discussion of the ROTE vehicles and of the required capacity and construction operations for minimal roads. The preliminary assessment of the concept's feasibility includes discussions of costs for (1) road construction and maintenance, (2) three examples, and (3) vehicle operation, and discussion of potential usefulness of the concept for (1) law-enforcement agencies, (2) passenger transportation, and (3) freight hauling. There is a comparison of minimal- and conventional-road investment and return.

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KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
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Remote Area Land Transportation	8, 4, 9					
Transportation	4, 9					
Land	9					
Remote	0					
Areas	9					
Vehicle-Roadway Combination	10, 8					
Vehicles	10					
ROTE Vehicles	8, 10					
Roads	10, 49					
Specifications	8					
Capacity	4					
Operations	4, 9					
Minimal	0					
Costs	8					
Construction	4, 9					
Maintenance	4, 9					
Utilization	8					
Passenger Transportation	4					
Law Enforcement	4					
Freight Transportation	4					
Comparison	8					
Conventional	0					
Investment	9					
Return on Investment	9					
Economic Evaluations	8					

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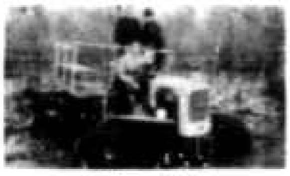
INFORMATION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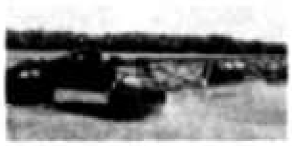
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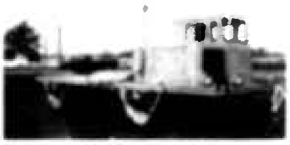
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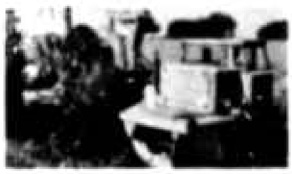
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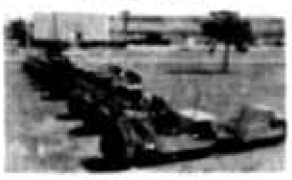
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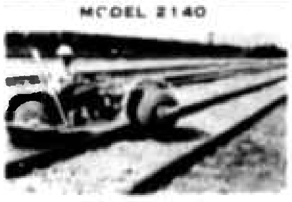
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Subject: Report No. RACIC-TR-59
Prepared for ARPA-Project AGILE:
"A Feasibility Study of a Remote
Area Land Transportation Concept"

Gentlemen:

At the time the subject report was being prepared by RACIC, Battelle Memorial Institute, several modifications were made on the Rolligon Model 4450. Attached is an up-to-date data sheet describing the characteristics of Rolligon Corporation's Model 4450. If you will insert this data sheet in Appendix A, Page A-1 of your report it will be current.

Rolligon Corporation's sole business is the design, development and manufacture of off-highway equipment, therefore, we are always glad to collaborate and cooperate with U. S. Government agencies or its contractors to resolve mobility problems so frequently encountered in many parts of the world.

If we can be of any assistance to you please let us know.

Yours very truly,

John G. Holland

John G. Holland, Sr.
President

JGHSr:bg
Attachment

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The Marsh Skeeter delivers the payload — over deep mud, marshes, swamps, delta areas, sand dunes, muskeg, snow, and inland waterways. This amphibious vehicle, while operating on-the-job with full payload in Louisiana swamps, Gulf Coast marshes and deep in Southeast Asian jungles, has proven its ability to operate effectively in all types of off-highway terrain.

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Specifications: Model 4450

Payload: 2,500 lbs. on land. 1,500 lbs. on water*

Engine: Four Cylinder. 172 cu. in. displacement gasoline; diesel optional

Transmission: 4 speed and reverse, manual shift

Axles: Spicer. No spin differentials

Brakes: Drive Line, hand lever. foot brake optional

Electrical System: 12 volt

Instruments: Ammeter, Hourmeter, Oil & Water Gauge

Tires: Four 40 x 50 Rollitires mounted on Aluminum wheels, all powered. Steel wheels optional*

Cargo Deck and Support Assembly: Aluminum. Steel optional.*
Deck size: Area — 31 sq. ft.
Width — 6 ft. 1 in. Length — 5 ft. 1 in.

Frame: Steel, fully articulated.

Drawbar Pull: 90% GVW on dry land. 50% GVW in mud.

Curb Weight: 3,200 lbs.*

Width, Overall: 9 ft. 11½ in.

Length, Overall: 13 ft. 0 in.

Height, Overall: 6 ft. 11 in.

Wheel Base: 100 in.

Ground Clearance: 20 in.

Gradeability: Forward slope 60%
Side slope 45%

Angle of approach: 60°

Angle of departure: 80°

Ground Bearing Area: 2800 sq. in.
700 sq. in. per tire

Fuel Tank Capacity: 8 Gal.

Average Fuel Consumption: 1 GPH

Top Speed: Land, 30 MPH
Water, 3 MPH

*Steel Cargo Deck & Support Assembly and Steel Wheels increase curb weight 400 lbs., decrease Payload on Land to 2,100 lbs. and to 1,100 lbs. on water.

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